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Scheme of program cooperation between participants of regional innovation system

Rodionov D.G.^a, Rudskaia I.A.^a, Gorovoj A.A.^a, Kudryavtseva T.J.^{a*}^a*Peter the Great St.Petersburg Polytechnic University, St Petersburg, Russia*

Abstract

The paper analyses modern methods, used to forecast means and ways of object transformation in complex management systems. A complex dynamic system is defined as a system that is characterized by a high level of contradictions between efficient economic entities, between enterprises and investors, between enterprises, investors and executive authorities, managing innovative activity in the region. Under consideration and analysis are also various ways of designing cooperation strategies between the participants of a regional innovation system, as well as the structure and elements of a regional innovation system and its participants. The article demonstrates methodological approaches to the development of management schemes, contributing to development of efficient regional innovation systems.

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1. Introduction

Today the target of the economy of the Russian Federation is to achieve national competitiveness. One of the most important strategic tasks of the country is to increase regional capitalization. The target of the region, in its turn, is to increase the cost of assets. Thus, state authorities and other participants of the regional innovation systems – enterprises, R&D centers, universities etc. – take active steps. Unfortunately, under current conditions, the efficiency of innovative process management decreases, which is related to the differences in the economic development of the regions of large countries. The regional aspect becomes more and more important in innovative processes, which is proved by the papers of the majority of modern researches (Belomestnov, 2006; Dandon, 2006; Chernorutsky, 2004;

* Corresponding author. Tel.: +7-921-340-1654.

E-mail address: tankud28@mail.ru

Rodionov, Sedov, 2013; Roisman, Grishina, 1998; Rudskaya, 2013; Falaleev, 2010; Lundvall, 1998; Roberts, 1999).

Thus, finding effective ways of manageable development and cooperation between the participants of the regional innovation system, ensuring their dynamic development with a view to increase innovative activity of the region is a burning issue today.

The performed analysis of the structure and elements of the regional innovation system allows defining it as a complex dynamic system with a high level of contradictions between economic entities, enterprises and investors, investors and executive authorities that manage innovative activity in the region. Consequently, a potential increase of innovation resources of the region depends on both: external managerial influence (state management) and the way the elements of a regional innovation system work together. This cooperation, its features, determine at the end of the day development of the regional innovation system and the ways of increasing innovative activity of the region.

Therefore, another important issue is to find effective ways of manageable development of the regional innovation system actors, ensuring their dynamic cooperation with a view to increase innovative activity of the region. That is why it is necessary to evaluate systematic features of manageability of economic entities, belonging to a regional innovation system – centers of knowledge generation, innovation-active enterprises, and organizations of innovation infrastructure.

2. Literature Review And Hypotheses

An innovation-active enterprise or an organization, belonging to innovation infrastructure (business incubator, techno-park) is an element of regional innovation system and an object of management. It means that it is quite a complicated subsystem, converting input managerial impacts $Y(t)$ (means a list of state measures, undertaken in a certain period of time, aimed at supporting innovative activity) into output signals (paths) $M(t)$. These paths characterize final comprehensive economic state of a managed object at a certain moment of time t , assessing manufacturing facilities, finances, intensity of innovative activity, number of realized projects, number of registered intellectual property assets, and other parameters (Vinogradov, 1985; Chernorutsky, 2004).

As a regional innovation system includes elements that develop in a figuratively objective way (population growth, real income dynamics etc.), there is a link between the object and environment - $C(t)$. It indicates a development function of the external economic environmental impact on the objects of management. We cannot manage this impact, but can observe the consequences of it. $R(t)$ means a vector of disturbances, that we can neither manage nor observe (internal and external impacts on an innovation-active enterprise) (Vinogradov, 1985).

Under the analogue of the entity development process, we understand f^* operator, connecting entity's input and output (Vinogradov, 1985):

$$M = f^*(C, Y, R) \quad (1)$$

Complexity characteristics of a managed item are the following (Vinogradov, 1985):

1. f^* operator is not described.
2. Inevitably non-evident, anti-intuitive behavior of the item.
3. Non-stationary state (changeability in time) of f^* operator.

A state may be evaluated with a special algorithm, providing for optimization. The sequence of a state evaluation and its setting algorithm are defined based on the evaluations, received in the course of modeling of a managed item (parameters of a built model based on the identification algorithm). In reality, when the elements of the system are managed, not all of the stated algorithms may be used.

When management processes are being revealed, the model of organization behavior shall be defined, which converts input signals into output ones in a certain way. This model allows forecasting system element behavior. Based on it, it is possible to increase the efficiency of managerial decisions.

Surplus topological structures form a methodological basis for the development of the existing and desired item behavior model. First, a surplus structure is formed, and then parameters are identified based on the available information base, which leads to the development of a complex model of organization behavior. Certain elements are excluded from the model (having, for example, zero value of certain parameters) (Quingrui, 2012).

In the present model an operator is determined by two types (groups) of parameters (Vinogradov, 1985):

$$f = \langle A, B \rangle \quad (2)$$

Let us assume that we have data about the structure of model operator. Now we need to identify the parameters. For this purpose, Volterra's models can be used (Vinogradov, 1985).

Let us outline the essence of the approach. Model's operator is given within the accuracy of the unknown parameter vector B:

$$M = f(C, Y, B) \quad (3)$$

If this entails management system design, then

$$M = f^*(C, B) \quad (4)$$

Managed input Y of the object is absent here.

The behavior of the item is characterized by certain information, which forms the basis of non-correspondence function ε of outputs of a model and an object. For example, in the simplest case we can take the following (Vinogradov, 1985):

$$\varepsilon(t, B) = \sum_{i=1}^m [M_i(t) - M_{iM}(t, B)]^2 \quad (5)$$

$M_i(t)$ – “response” in point of i output of the present complex object to the impact $C(t)$;

$M_{iM}(t, B)$ – expected “response” of the model, describing organizational behavior (estimated impact on the input is measured and described).

After that an objective function is formed, it is minimized, and thus a parametric identification is made. For example, this objective function may look like that (Vinogradov, 1985):

$$I(B) = \sum_{k=1}^N \varepsilon(t_k, B) \rightarrow \min \quad (6)$$

It is assumed, that the vertical sum of the non-correspondence function is minimized at the finite set of points t_k . Target functions are minimized with the methods of parametric optimization. In the result of it, a desired appropriate vector of parameters B is determined (Vinogradov, 1985).

The function of the minimum is more often used for a parametric identification. Methods of identification are researched in the papers of L.A. Rasstrigina and N.E. Modzharova (1980; 1987)

We turn now to the active identification. It is evident that all types of identification, active, as well as passive, may be performed continuously, also in the course of managerial activity itself. It allows making amendments to the model immediately. Usually, the following types of assessments, used for dynamically changing objects, are taken into consideration (Vinogradov, 1985): smoothing, screening and forecast.

When management processes are determined (identification), the best model of the system element development is elaborated (with regard to a set criterion). Such system element is, in its turn, a complex object. It is determined on the basis of the best assessment of the object state (with regard to identified criterion). Solution to the problem of optimization is also the basis for determining the management configuration and development vector of an object of management.

Consequently, the result is formation of an optimal mode of processes and optimal strategy, which application allows maintaining a necessary mode in the conditions of internal and external impacts.

Below is the formal representation of the task to forecast optimal variant of development of a selected enterprise, innovative complex of a region or any other complex object (Lundvall, 1998):

$$y_i(x, R) \leq t, t \in P^1, i \in [1:m] \quad (7),$$

These inequalities describe conditions of efficiency.

x – Variant vector of alternative development indicators (parameters).

R – Vector of collection of influencing factors of external environment uncertainty (inflation, changes of refinancing rate, location of enterprises and resources etc.).

P^1 – one-dimensional Euclidean space, corresponding to a time scale (Quingrui, 2012).

Let us define an optimization problem. One of the settings may be related to the search for the course of development (vector x), satisfying certain conditions (Quingrui, 2012).

$$x \in \arg \min_x I(x) \quad (8)$$

In such case, the function $I(x)$ characterized the property of possible solutions to the inequalities (7).

In the mentioned problem setting, an enterprise, actively involved in innovations, is a participant of the regional innovation system and is taken as a static object, while the parameters of management are described with x vector. This object is managed based on the application of the management theory postulates.

The object operator is understood as an algorithm, determining output parameters y that result from parameter x transformation.

According to the management theory of complex systems, the execution of this algorithm is called “solution to the problem of analyzing a design object” (Belkov, Lanshakov, 2009). As a rule, a diversity analysis is performed, which implies using a set of transforming input parameters.

Let us consider the block-structure of a design based on optimality (Belkov & Lanshakov, 2009). Each block is a stage of managerial decision-making.

Block 1. The main parameters of the designed object are determined: fixed and floating assets, need of financial resources and their sources etc.

Block 2. Initial vector x is determined. It is made based on initial information.

Block 3. Design object is analyzed. It means to determine parameters based on built parameters x .

Block 4. Optimality criteria are determined. Function $I(x)$ is set based on a vector c . This function characterizes project quality, which corresponds to the given x value.

Block 5. Parametric optimization algorithm is applied (management device). Optimization is related to anti-crisis management. Function I implies that vector R is taken into account.

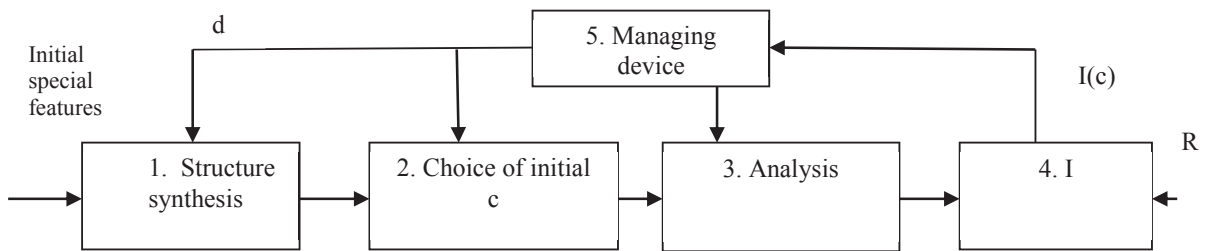


Fig. 1. Optimal design: block-structure of decision-making steps

Relation d shows, that it is necessary to come back to the first stage if a received current structure does not satisfy the set requirements. If there are no more variants of possible structures, it is possible to change a list of requirements (Belkov & Lanshakov, 2009). It should be pointed out that this block-structure does not imply closureness. To obtain an appropriate managerial decision means to leave the algorithm. Besides that, it is possible to leave the algorithm, when there is no optimal decision according to the set criteria.

The features of complex economic systems in actions, with regional innovation system being a part of them, show that sustainability of the system is a prerequisite of successful interaction between its participants. Regional executive bodies shall coordinate innovation programs of the enterprises and organizations of the infrastructure, because they are the main bodies, distributing the state budget. In crisis conditions, it is necessary to harmonize activities aimed at stimulating innovative activity, providing regional innovative process participants with sources of financial resources, which requires development and implementation of corresponding support programs by executive bodies.

3. Methodology

The main method of regional innovative policy implementation is special program and purpose planning. Activities are financed based on regional innovation programs.

Let us select a multitude of variants of regional innovation program implementation (VRIP): $L = \{l_j; j=1, \dots, J\}$. In such case, the interests of governing bodies and enterprises do not coincide (Rasstring, 1980; Rasstring & Modzharov,

1987)

Let us write a set of regional innovation system participants $\Pi = \{\pi_i; i=1, \dots, I\}$. Their interests are represented as investments resources, allocated to the program. Investment expenditures, related to the program implementation, are described by set $C_j; j=1, \dots, J$. The limit of allocated financial resources of each participant a_i . In a preferred j VRIPI, a participant may invest funds S_{ji} . Total amount of finance for regional innovation programs is limited (Rasstring, 1980; Rasstring & Modzharov, 1987).

The task is to choose a variant that satisfies to the maximum extent the interests of all the participants. Let us formalize it.

Vector c consists of 1 and 0. Value 1 is assigned, if a regional program is preliminary chosen for consideration, 0 – if it is not chosen. Vector y also consists of 0 and 1. The value is 1, if a j variant is provided with funds, 0 – if scarcity of funds is observed.

The total deficit of funds related to the discussed variants, may be represented as follows (Rasstring, 1980; Rasstring & Modzharov, 1987):

$$f(x_j) = \sum_j C_j \cdot x_j - \sum_i S_{ji} \cdot x_j, \text{ where } \psi_j = C_j \cdot x_j - \sum_i S_{ji} \cdot x_j > 0 \quad (9)$$

Function of the deficit of funds will be as follows

$$f(x_j) = \sum_j \psi_j \cdot x_j \quad (10)$$

Function of the provision of funds is $y_j - (11)$.

These two criteria correlate. It is necessary to achieve (Rasstring, 1980; Rasstring & Modzharov, 1987)

$$\max \sum_j Y_j, \min \sum_{ji} \Psi_j \cdot x_j \quad (12)$$

Let us represent financial participation in the implementation of programs of regional innovation system actors in the form of a matrix.

$B = \|b_{ji}\|, j=1, \dots, J, i=1, \dots, I$, Matrix element is equal to 1, if i participant finances j variant (S_{ji} more than 0), 0 – if it does not participate in financing (S_{ji} is equal to 0).

Let us introduce a function, based on which the number of financially provided variants by the participant j of regional programs (Rasstring, 1980; Rasstring & Modzharov, 1987):

$$\vartheta_i = \sum_j b_{ji} \cdot y_j \quad (13)$$

In this case, every participant tries to achieve

$$\max \sum_j b_{ji} \cdot y_j \quad (14)$$

Thus, the interests of regional innovation system participants are harmonized.

Further intensification of the function (14) consists in provision (Rasstring, 1980; Rasstring & Modzharov, 1987):

$$\max_i \sum_j \max_j \sum_j b_{ji} \cdot y_j \quad (15)$$

It brings benefit not only to the participants of the regional innovation system, but also to the participants of the federal level.

Let us set an optimization problem to choose VRIPI (Rasstring, 1980; Rasstring & Modzharov, 1987):

$$\sum_j \psi_j \cdot x_j \rightarrow \min \quad (16)$$

This criterion is achieved with regard to the following limitations:

- 1) total amount of program financing by participants:

$$\sum_i S_{ji} \cdot x_j \leq a_i \quad (17)$$

- 2) total amount of financing by governmental bodies for all the discussed joint programs:

$$\sum_j \sum_i S_{ji} \cdot x_j \leq P \quad (18)$$

In such a setting all, the variants are equally important for all the participants. However, the participants of the federal management level may follow special priorities. In order to realize these priorities, they may increase maximum financing of the programs, desired from the point of view of national economy (using the funds of the federal budget, as well as special forms of innovative enterprise support).

The interests of the federal bodies are as follows (Rudskaya, 2013): to involve innovative enterprises into programs to the maximum extent, reduce the deficit of funds. In such case, a multi-criteria task may look as follows (Rasstring, 1980; Rasstring & Modzharov, 1987):

$$\sum_j x_j \rightarrow \max \quad (19)$$

$$\sum_j \Psi_j \cdot x_j \rightarrow \min \quad (20)$$

$$\sum_j y_j \rightarrow \max \quad (21)$$

with limitations (10, 12).

Let us present the stages of this problem solution.

1. A set of initial managerial information is formed:

$$S = \|S_{ji}\|, j=1, \dots, J, i=1, \dots, I, C_j, a_j.$$

2. L variants are considered (with regard to subsets):

$$L^1 = \{L_j; \psi_j \leq 0\} \text{ and } L^2 = \{L_j; \psi_j > 0\} \quad (22)$$

3. At zero value of L^1 point 7 is realized.

4. For all the elements $L_j \in L^1$ the following is assigned: $x_j = 1$. The value is calculated:

$$\sum_j y_j \text{ по } \forall L_j \in L^1 \quad (23)$$

5. If limitation (22) is fulfilled, point 7 is further realized.

6. Plans are gradually excluded from L^1 set with value $\min_j C_j$. As soon as the limitation is fulfilled:

$$P - \sum_{L_j \in L^1} \min_j C_j \leq 0. \quad (24)$$

point 8 is realized.

7. L^2 set is arranged in ascending order of the elements ψ_j . $x_j=1$ is assigned to the first element of L^2 set. Condition (24) is checked. If it is fulfilled, the next element is set equal to one. If a limitation is not fulfilled, we turn to point 8.
8. Solution to problem $X = \{x_j; x_j=1\}$, values of functions are determined:

$$\sum_j y_j \text{ and } \sum_j \Psi_j \cdot x_j \quad (25)$$

Limitation (24) lies within control zone of regional innovation system participants, so it is constantly fulfilled.

It is always possible to determine value (24). Solution resolves itself to the search for a set of variants $L^1 = \{L_j; \psi_j \leq 0\}$, provided with financial resources. L^1 set ensures that the values of functions (19) and (21) coincide.

Minimum value of function (20) is 0.

If limitation (19) is fulfilled, it is possible to make the value of function (21) better, however the values of function (24) become worse and vice versa. Function (25) does not change. Consequently, the problem reduces itself to the compromise between the values of functions (21) and (24), with regard to limitation (19).

Thus, algorithm of problem solution is formed (16)-(21).

This algorithm was presented with supposition that the amount of innovative program financing by regional innovation process participants was known.

Now let us assume that the amount of financing is not fixed, it may be changed in order to find a harmonized managerial decision (when the majority of the participants are satisfied with such a decision).

In this case only upper limits of funds allocation are set, and within them the participants may increase or decrease corresponding expenditures related to the programs of their interests. Matrix B is formed.

Then the task is to distribute the funds of federal and regional budgets and other participants so that as many programs as possible are financed, which is of interest for all the parties and meet the interests of national economy development.

Let us formalize this problem.

$$x_j = \begin{cases} 1 & \text{if } j \text{ VRIPI is included in the content of discussed variants,} \\ 0 & \text{if not} \end{cases}$$

Z_{ji} – amount of financing, allocated by i participant for j program.

J program receives sources a of financing, if:

$$y_j = \begin{cases} 1 - \text{если } C_j \cdot x_j - \sum_i Z_{ji} \cdot x_j \leq 0; \\ 0 - \text{если } C_j \cdot x_j - \sum_i Z_{ji} \cdot x_j > 0, \end{cases}$$

Each participant maximizes their benefit (profit):

$$\sum_j b_{ji} \cdot y_j \quad (26)$$

Which means:

$$\max_i \sum_j \max_j \sum_j b_{ji} \cdot y_j \quad (27)$$

Total finances of the participants are limited:

$$\sum_j b_{ji} \cdot Z_{ji} \cdot x_j \leq a_i \quad (28)$$

To fulfill the condition of maximization means that each participant gets benefit and that there is a general benefit (that may be interpreted as benefit for national economy).

Each participant will participate in non-priority financing of all the programs of their economic interest (“metered” strategy of financing). If financing is done equally, then:

$$Z_{ji} = \left\lfloor \frac{a_j}{\sum_j b_{ji}} \right\rfloor \quad (29)$$

Obtained value is rounded to the next bigger whole number.
Values

$$\left\lfloor \frac{C_j}{\sum_i b_{ji}} \right\rfloor \text{ и } \left\lceil \frac{C_j}{\sum_i b_{ji}} \right\rceil \quad (30)$$

- are, in fact, amounts of minimum and maximum financing of j VRIPI, which means they determine the limits of values Z_{ji} .

For the first value, the following limitation is checked:

$$\sum_i Z_{ji} \geq 0 \quad (31)$$

In case of fulfillment, the amounts of financing are determined. If not – they increase to the maximum. When the values Z_{ji} are set, variant L_1 is included in the total (which means $x_1=1$) and values are recalculated for each party:

$$\Delta_i^{*T} = \sum_j b_{ji} - 1, \quad a_i^T = a_i - Z_{ji} \quad (32)$$

where Δ_i^{*T} and a_i^T – current values when the algorithm is effective.

Then the next variant is chosen and actions (29, 30) repeat. The condition of the end of algorithm's efficiency will be the following:

$$a_i = 0 \text{ for } \forall i=1, \dots, I \quad (33)$$

Let us represent the stages of problem setting and solution (28– 33),:

1. A set of initial managerial information is formed:

$$B = \|b_{ji}\|, j=1, \dots, J, i=1, \dots, I, a_i.$$

2. A set of variants L in Matrix B is arranged in descending order Δ_j .
3. Participants Π in matrix B are arranged in descending order Δ_i^* .
4. j VRIPI is chosen from an arranged set L . Values Z_{ji} for j variant are calculated by formula (22).
5. For j VRIPI under consideration, current values Δ_i^{*T} and a_i^T are calculated. Condition $a_i = 0$ is checked. If it is not fulfilled – we come back to step 4.

4. Conclusion

Thus, we can draw the following conclusions from the above mentioned:

- innovation-active enterprises and regional innovation system can be treated as complex objects of management;
- complex objects of management have specific features and it is possible to forecast the paths of their development on the basis of optimization concept. Moreover, it is applicable to both: selected enterprises and regional innovation system in general;
- methods if the theory of management is efficient for finding managerial solutions for regional innovation system, for which formalization a large number of optimization problems may be used (finding maximum or minimum of objective functions at a certain set of vectors).

It is a tool of quantitative research and forecasting of the development of the system of interacting innovation-active enterprises and regional innovation system in general.

We would also like to note that the proposed scheme of program cooperation performs a multi-criteria task, taking into account various interests of all the participants of a regional innovation system in the course of any program implementation. The proposed scheme allows choosing a variant of regional innovation program implementation based on the formation of collective target of the parties. Simultaneously the benefit of every participant and total benefit from the financing of regional innovation programs maximize.

When the proposed scheme of program cooperation between the participants of regional innovation system is applied, it becomes possible to take into account the amount of money allocated to the implementation of regional innovation programs for each actor of a regional innovation system. This condition is an unquestionable advantage of the proposed scheme and allows developing a harmonized managerial decision, shared by either all the participants of a regional innovation system or the majority of them.

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